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Lake Trout Studies in the AYK Region, and Burbot Index of Abundance in Galbraith Lake, 1994

by

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November 1995

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	$>$
greater than or equal to	≥
harvest per unit effort	HPUE
less than	$<$
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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by

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Stock status of lake trout *Salvelinus namaycush* in Galbraith Lake was described by estimates of population abundance, size composition, and catch per unit effort (CPUE) during June 1994. Estimated abundance of lake trout in Galbraith Lake was 236 fish (SE 41 fish) > 499 mm FL. Lake trout less than 500 mm FL were rare in catches with all gear types and were assumed to have low abundance. CPUE from standardized (Index) gillnet catches were also very low; 0.21 lake trout per gillnet hour. Most (63%) lake trout were between 500 and 600 mm FL with few (5%) fish larger than 700 mm.

Index gillnetting was conducted at Irgnyivik, Nanushuk, and Itkillik lakes on the north slope to characterize length distribution of lake trout and to estimate CPUE. Bimodal length distributions, which are believed to be characteristic of unexploited lake trout populations, were not observed in the samples. The CPUE of lake trout from the three lakes which are remote from road access was much higher than results from road accessible lakes: Irgnyivik Lake, 2.9 fish/net h, Nanushuk Lake, 7.4 fish/net h, and Itkillik Lake, 9.6 fish/net h.

Lake area, depth and temperature data were obtained from 14 Arctic lakes. Estimates of potential yield of lake trout calculated from the limnological data ranged from 0.2 to 5.0 kg/hectare/year.

Only one yearling lake trout was captured in Sevenmile Lake during September 1994. In September 1993, 107,000 fertilized eggs were taken from the population for rearing in Clear hatchery. Lake trout of known age were sampled for an ongoing age validation study.

CPUE of burbot *Lota lota* ≥ 450 m TL captured in hoop nets in Galbraith Lake, used as an index of abundance, was 0.216 fish/net set indicating low population abundance.

Key words: lake trout, *Salvelinus namaycush*, burbot, *Lota lota*, CPUE, population abundance, length composition, limnological parameters, potential yield, Thermal Habitat Volume, age validation, Galbraith Lake, Irgnyivik Lake, Namushuk Lake, Itkillik Lake, Sevenmile Lake.

INTRODUCTION

BACKGROUND

It is likely that the level of fishing effort directed at lake trout and other game fish species in Galbraith Lake and other nearby waterbodies will increase markedly in the next few years. The U. S. Bureau of Land Management (BLM) has plans to construct a campground and boat launch at Galbraith Lake. Presently, there is no direct road access provided to the lake. The road, campground, and boat launch are to be constructed in anticipation of opening the Haul Road (Dalton Highway) north of Atigun Pass to public travel. In addition, road access is needed to a large waterbody in order to provide a site for floatplane fueling and loading. Increased access to Galbraith Lake (by road) and other area lakes (by float plane) will likely result in increased fishing effort and harvest. Baseline population data from these lakes are necessary to assess the anticipated impact resulting from increased use of the area. Significant exploitation would likely result in changes in size composition of game fish species particularly lake trout. Lakes which were selected for sampling in 1994 were Galbraith Lake, Irgnyivik Lake, Nanushuk Lake, and Itkillik Lake

Johnson (1976) and Power (1978) describe catches of lake trout from unexploited Arctic populations as being bimodal with abundant large fish (>750 mm FL), abundant small fish (< 650 mm FL), and nearly no fish in between. The presence of such a distribution would indicate that the population is relatively unexploited and is likely at carrying capacity for the lake. A population which is expected to be relatively unexploited could be sampled to obtain length distribution as a quick assessment of the level of exploitation. If the distribution of lengths sampled does not fit the bimodal pattern of Johnson (1976) and Power (1978), exploitation may have changed the virgin stock structure. For example, a uniform distribution might indicate that significant exploitation already exists or that mortality of large fish is high. Alternatively, a normal distribution might indicate that large fish had been cropped off or that only large fish are present and that recruitment is limited. If a bimodal distribution of Johnson (1976) and Power (1978) is not observed in the sample, a mark-recapture experiment should be considered for a subsequent season to assess the population.

Lake trout density and production have been related to various physical characteristics of the lakes in which the species is found. To better understand the relationships between physical habitat and lake trout populations in Alaska, data from a large number of lakes of diverse size and type will be required. Accumulation of these physical data will be combined with collection of biological population data.

Burr (1994) estimated that at least 20% of the potential annual egg production was removed from the lake trout population in Sevenmile Lake during the 1993 egg take. It is not clear whether replacing this lost recruitment by stocking yearlings would result in a net loss or gain to the population. To assess the potential impact of replacing the lost recruitment to age-1 with hatchery fish, the growth to age-1 for fish in the population prior to (and after) 1993 will be compared with growth of the 1993 age group. If it is found that the 1993 fish grew faster, this may be evidence that growth compensation and presumably increased survival occurred. If there is not a change in growth rates for yearling fish, no compensatory growth and or survival is indicated and modest supplemental stocking may be recommended.

Objectives for Stock Assessment

To describe the stock status of lake trout in Galbraith Lake and to investigate the utility of Index Fishing as a tool to assess lake trout stock status, the following objectives were addressed in 1994:

1. estimate abundance of lake trout in Galbraith Lake;
2. index abundance of burbot in Galbraith Lake larger than 300 mm TL as mean catch per effort (CPUE) in hoop nets;
3. estimate length composition of lake trout in Galbraith Lake;
4. determine which of three distributions (uniform, bimodal, or normal) best fits lake trout length distributions taken in Galbraith Lake, Nanushuk Lake, Irgnyivik Lake, and Itkillik Lake; and,
5. estimate mean length and weight of yearling lake trout in Sevenmile Lake in September 1994.

In addition to these primary objectives, the following tasks were addressed:

1. measure or calculate selected limnological parameters for study lakes including Lake Area, volume, maximum and mean depth, and temperature;
2. calculate potential yield of lake trout for selected lakes from limnological parameters using Thermal Habitat Volume and Lake Area models;

3. validate that ages of lake trout stocked in 1991 as determined from otoliths, opercular bones and scales are true ages; and,
4. estimate CPUE with standardized gillnet sampling (Index Fishing) for lake trout in Galbriath Lake, Nanushuk Lake, Irgnyivik Lake, and Itkillik Lake.

Research relating to index abundance of burbot in Galbraith Lake is addressed in Appendix A.

METHODS

COLLECTION OF SAMPLES

Sampling was conducted at four lakes on the north slope of the Brooks Range: Galbriath Lake, Nanushuk Lake, Irgnyivik Lake, and Itkillik Lake (Figure 1) and at Sevenmile Lake located on the Denali Highway near Paxson in the Alaska Range (Figure 2). In the north slope lakes, fish were captured in gillnets following the sampling protocol of Lester et al. 1991 (Appendix B). In Galbraith Lake, fish were also captured in minnow traps, in fyke nets, and in hoopnets set in transects according to protocol of Bernard et al. 1991. Minnow traps are similar to the hoop nets described in Appendix A except that they are smaller and were baited with salmon eggs rather than with cut herring. The minnow traps were 1.8 m long with five 0.6 m to 0.5 m diameter hoops. The traps were stretched with 25.4 mm PVC pipe attached with snap clips at end hoops. Each fyke net is 6.1 m long composed of a double square 1.2 m aluminum frame and four steel hoops measuring 0.9 in diameter. The traps have three throats; one attached to the square frame, the others attached to the first and third hoops. Attached to outer sides of the square frame are 7.6 m long by 1.2 m deep seines which funnel fish toward the trap. All mesh is 9.5 mm nylon webbing. The fyke nets were set facing the shore line with 15.2 m to 30.5 m seines attached to shore and to the center of the square frame.

LAKE TROUT ABUNDANCE - GALBRAITH LAKE

Abundance of lake trout in Galbraith Lake in 1994 was estimated with a Petersen mark-recapture experiment (Seber 1982). Lake trout were marked with individually numbered Floy anchor tags and with adipose fin clips. Sampling to mark lake trout occurred between June 21 and 30, 1994. Recapture sampling occurred between August 4 and 11. The estimate of abundance is germane to the time of marking (late June), 1994. The abundance and the variance of the estimate was calculated as follows (Seber 1982):

$$\hat{N} = \frac{(C+1)(M+1)}{(R+1)} - 1 \tag{1}$$

$$\hat{V}\left[\hat{N}\right] = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \tag{2}$$

where:

M = the number marked and released alive during the first period;
C = the number examined for marks during the second period; and,
R = the number recaptured during the second period with mark from the first period.

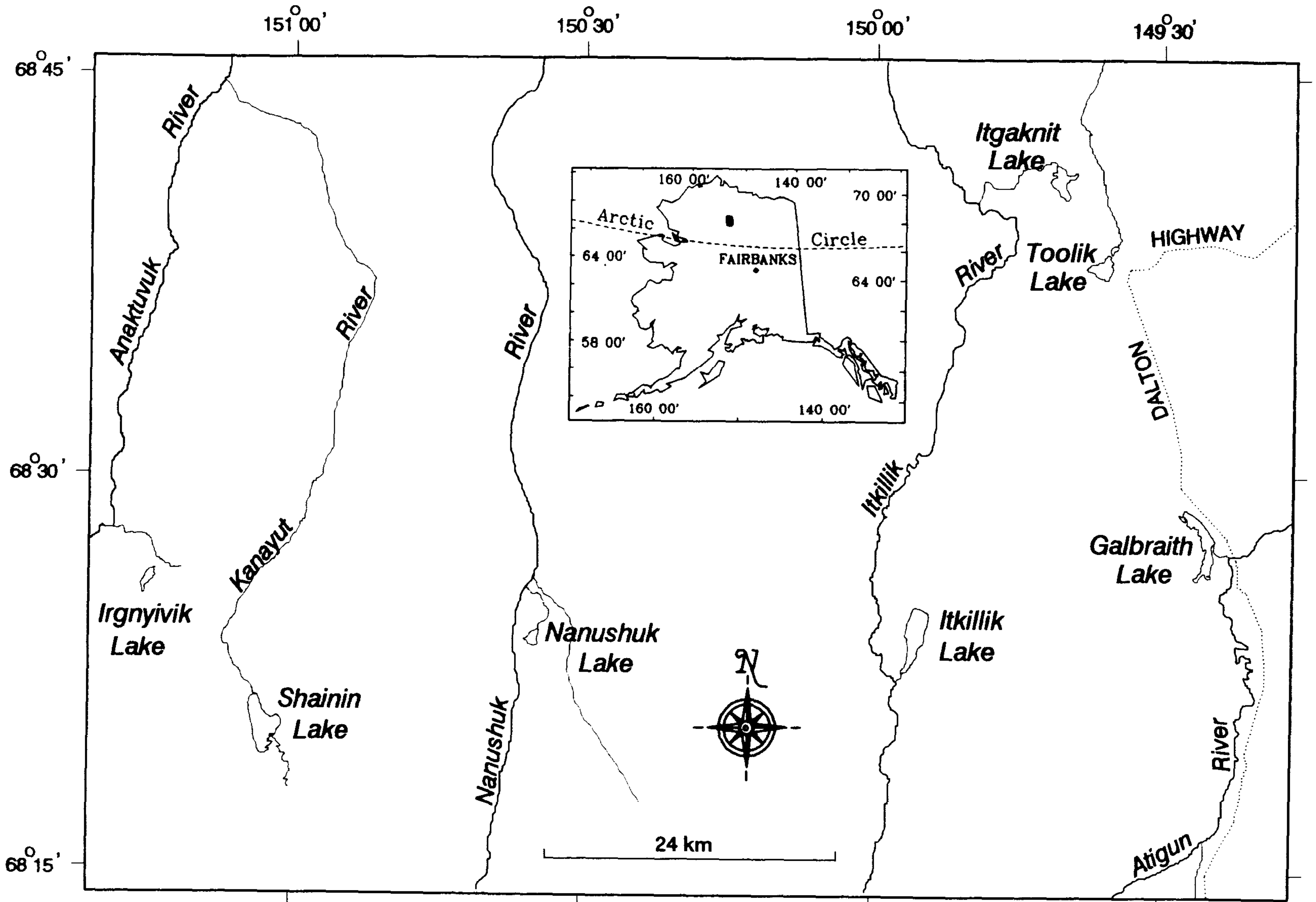

Figure 1.-Location of lakes sampled in 1994.

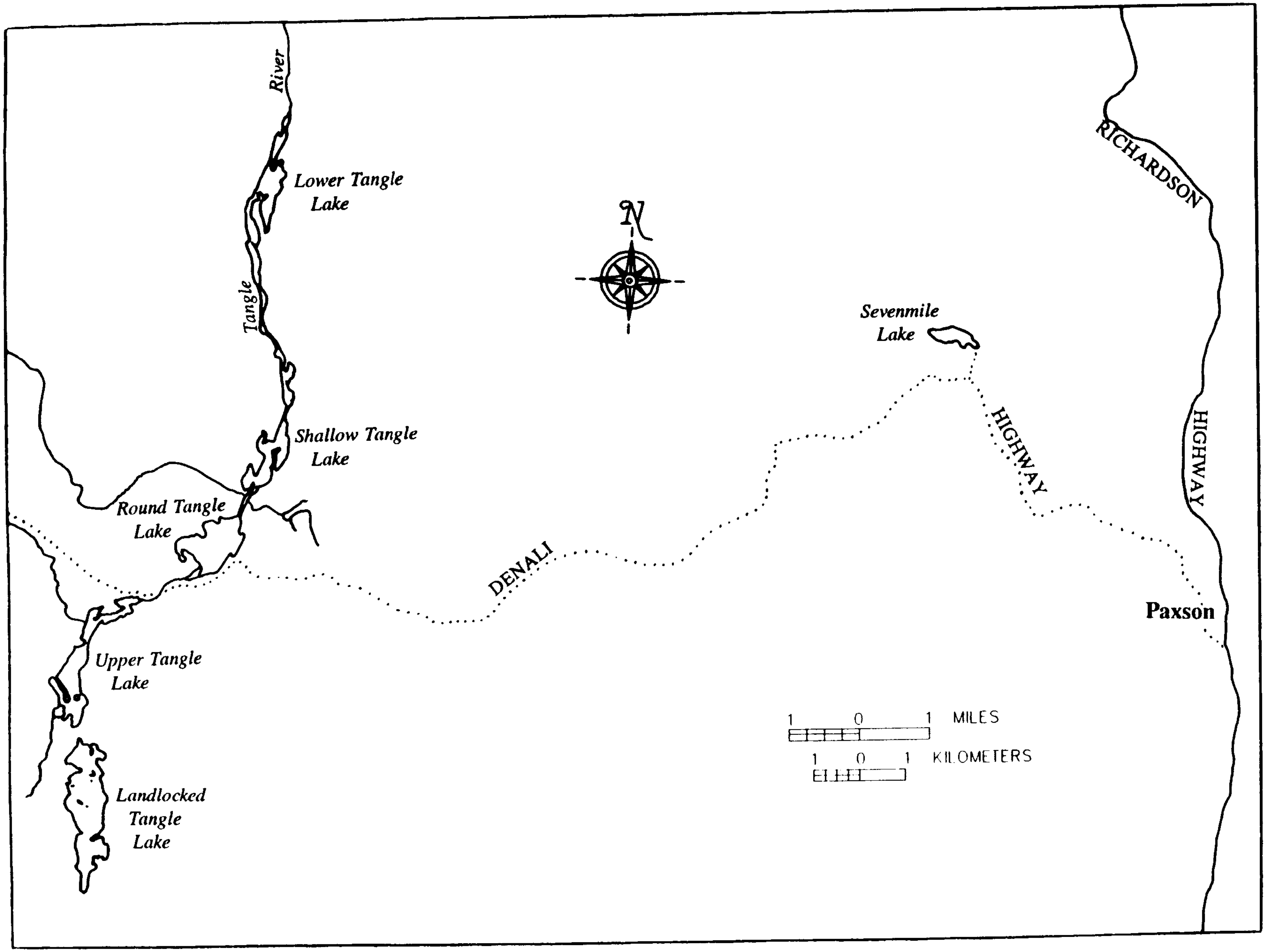

Figure 2.-Location of Sevenmile Lake near Paxson, Alaska.

The assumptions necessary for accurate estimation of abundance in a closed population are (from Seber 1982):

1. the population is closed (no change in the number of lake trout in the population during the experiment);
2. all lake trout have the same probability of capture in the first sample or in the second sample, or marked and unmarked lake trout mix completely between the first and second samples;
3. marking of lake trout does not affect their probability of capture in the second sample;
4. lake trout do not lose their mark between sampling events; and,
5. all marked lake trout are reported when recovered in the second sample.

Testing of Assumptions

Assumption 1 is likely valid. Suitable habitat for lake trout appears to be limited outside of the lake. To detect immigration or emmigration during both sample periods, test fishing was conducted within all of the streams entering or leaving Galbraith Lake. It is possible that immigration or emmigration occurred between sample periods (approximately one month). The likelihood that mortality or recruitment due to growth would occur between sampling events is low due to the short duration of the hiatus. Assumptions 4 and 5 were assumed to be valid because of double marking of tagged lake trout and rigorous examination of all captured lake trout.

Assumptions 2 and 3 were tested directly in two ways. First, changes in capture probability may have occurred within different parts of the lake. These potential changes were investigated by dividing the lake into two areas (north and south). To determine if capture probability did change between areas, the recapture-to-catch ratios of each area were compared using a chi-squared contingency table. The two rows of the table were the different areas and the two columns of the table were the number of recaptures in the area and the number of unmarked fish examined during the second event in the same area. If the recapture-to-catch ratios were significantly different ($\alpha = 0.05$), the data were stratified into areas and separate abundance estimates calculated for each area.

Secondly, capture probability may differ by size of fish. Two Kolmogorov-Smirnov (K-S) statistical tests were used to determine if capture probability differs by size of fish. The first K-S test compared the length frequency distribution of recaptured lake trout with those captured during the marking event. The second K-S test compared the length frequency distribution of lake trout captured during the marking event with those captured in the recapture event (see Bernard and Hansen 1992 for a description of tests). The first K-S test was used to determine if capture probability varied by size of fish. If significantly different, the size at stratification was determined by performing a series of chi-squared tests at differing sizes (using two size strata). The size at stratification that produced the largest chisquared value (the greatest difference in capture probability) was used to stratify the data for separate abundance estimation. The second K-S test was used to determine if size data needed to be corrected for changes in capture probability (see Length Composition below).

LENGTH COMPOSITION

Length composition of lake trout in Galbraith Lake was estimated as a multinomial proportion. Fish were sampled in Galbraith Lake using the Index Fishing protocol of Lester et al. 1991, (Appendix B) during sampling conducted for abundance estimation. Estimates of length composition are in terms of the proportion of fish in 25 mm length categories.

From tests of assumptions 2 and 3 for estimation of abundance, significant differences in capture probability by area and/or size of fish may be found. Differences in capture probability may also bias estimates of size compositions. If significant changes in capture probability were detected, size data were adjusted for these differences so that the size composition of lake trout could be estimated. First, the proportions of fish by length category were estimated as:

$$\hat{p}_j = \frac{n_j}{n} \tag{3}$$

where: $\hat{p}_j$ = the estimated fraction of the population that is made up of length category j, n_j= the number in the sample from category j, and n = the number of fish sampled.

Variance of this proportion was estimated as the variance of a binomial:

$$V(\hat{p}_j) = p_j \frac{(1 - p_j)}{n - 1} \tag{4}$$

The abundance of each length category was estimated from the proportions and abundance:

$$\hat{N}_j = \hat{p}_j \hat{N} \tag{5}$$

where $\hat{N}_j$ = the abundance of fish in length category j. The variance was calculated as:

$$V(\hat{N}_j) = V(\hat{p}_j)\hat{N}^2 + V(\hat{N})p_j{}^2 - V(\hat{p}_j)V(\hat{N}). \tag{6}$$

These average weighted proportions and variances by size were used as estimates of size compositions in the Galbraith Lake.

LAKE TROUT LENGTH DISTRIBUTIONS

Sampling was conducted in four Arctic lakes (Galbraith, Irgnyivik, Nanushuk, and Itkillik) to determine if the length distributions of the lake trout populations inhabiting these lakes were best described by a bimodal, normal or uniform distribution. Length distributions which are bimodal indicate essentially virgin populations while either normal or uniform distributions were taken as evidence that significant exploitation had occurred.

Fish were sampled using the Index Fishing protocol of Lester et al. (1991, Appendix B). Samples were collected from Galbraith Lake during sampling conducted for abundance estimation. Samples from the other three lakes were collected during sampling conducted during July. Distributions were examined to determine which of three (uniform, normal, or bimodal) best described the results. The length of the sampled lake trout were compared to theoretical normal, bimodal and uniform distributions. The theoretical distributions were transformed with the means, variances and ranges from the sample data. The *D* statistic from the Kolmogorov - Smirnov two-sample test, which measures the maximum deviation from the theoretical distribution and the data, was used to determine which of the three distributions best fits the data.

Selectivity of Index Gillnets

Selectivity of the three gillnet meshes was investigated by pooling samples from the four study lakes. First, the hypothesis that the cumulative distributions of fish caught with all three mesh sizes was the same was tested by using the Andersen-Darling test (Scholz and Stephens 1987). When (if) the hypothesis was rejected, K-S two-sample tests (Seber 1982) were used to determine where the differences were.

LIMNOLOGICAL PARAMETERS

Physical characteristics of study lakes were measured or calculated using standard methods. Parameters obtained include lake surface area, maximum and mean depth, and temperature at 1 m depth intervals.

LAKE TROUT YIELD

Potential yield of lake trout was calculated for the 14 lakes listed in Table 1 using the Lake Area model (Evans et al. 1991) and the Thermal Habitat Volume (THV) model (Payne et al. 1990). Both of these emperical estimators were developed from lakes in Ontario Canada by the Ontario Ministry of Natural Resources. The Lake Area model predicts yield from Lake Area alone. THV predicts maximum potential yield from the volume of lake water bounded by 8 and 12 °C during warmest summer weather.

For the Lake Area model, the relationship developed by Evans et al. (1991) is:

$$\log_{10} H = 0.6 + 0.72 \log_{10} A \qquad (7)$$

where

A = area measured in hectares, and

H = potential harvest (kg yr^{-1}). Potential yield (kg ha^{-1} yr^{-1}) can be obtained by dividing by area.

The THV model is based on the concept that carrying capacity is determined by the amount of suitable habitat. Carrying capacity in this case is represented by the availability, during summer, of water of a temperature range which is physiologically optimal for the species. For lake trout, this temperature range is estimated to be between 8 and 12° C. The relationship obtained by Payne et al. (1990) is:

$$\log_{10} H = 2.15 + 0.714 \log_{10} (\text{July THV}) \qquad (8)$$

where

H = potential harvest (kg yr^{-1}), and

July THV = thermal habitat volume calculated from July temperature data.

Table 1.-Lakes for which potential yield of lake trout was calculated from limnological parameters using Thermal Habitat Volume and Lake Area models.

Lake	Location	Surface Area (ha)	Max Depth (m)	Fish Species Present[a]
Agiak	68° 04'N, 152° 58"W	150	16	AC, GR, LT, RWF
Amiloyak	68° 06'N, 152° 52"W	100	10	AC, GR, LT, RWF
Chandler	68° 14'N, 152° 42"W	1300	20	AC, BB, GR, LT, RWF
Kipmik	67° 57'N, 156° 09"W	300	45	GR, LT, RWF
Matcharak	67° 45'N, 156° 12"W	280	20	GR, LT, LCI, RWF
Minakakosa	66° 55'N, 155° 00"W	330	50	HWF, LT
Takahula	67° 21'N, 153° 40"W	1800	55	GR, LT, NP
Narvak	66° 54'N, 155° 38"W	780	114	GR, LT, NP, RWF
Selby	66° 52'N, 155° 40"W	1000	33	GR, LT, NP, RWF
Walker	67° 07'N, 154° 22"W	3800	120	AC, BB, CS, GR, LCI, LT, RWF, NP
Galbraith	68° 28'N, 149° 25"W	412	7	AC, BB, GR, LT, RWF
Itkillik	68° 24'N, 149° 55"W	430	14	GR, LT, RWF
Nanushuk	68° 24'N, 150° 35"W	81	18	GR, LT
Irgnyivik	68° 27'N, 151° 15"W	87	17	GR, LT, RWF

[a] AC Arctic char *Salvelinus alpinus*, BB burbot *Lota lota*, CS chum salmon *Onchoryhnchus keta*, GR Arctic grayling *Thymallus arcticus*, HWF humpback whitefish *Coregonus pidschian*, LCI least cisco *Coregonus sardinella*, LT lake trout *Salvelinus namaycush*, RWF round whitefish *Prosopium cylindraceum*, NP northern pike *Esox lucius*.

Individual temperature profiles were measured at 1.0 m depth intervals and averaged across all sites to obtain a single temperature profile for each lake. The depths at which 8 and 12°C occur were interpolated from the final temperature profile. This single profile for each lake was used to calculate the volume of water between 8 and 12°C.

YEARLING LAKE TROUT IN SEVENMILE LAKE

Minnow traps and small mesh hoop nets baited with salmon eggs and unbaited fyke nets were set in all parts of Sevenmile Lake in mid September to capture yearling lake trout.

AGE VALIDATION

Lake trout of known age will be used to determine if ages estimated from otoliths, opercular bones, and scales represent the true ages of these fish. During June of 1991, a total of 52,900 young of the year lake trout were released into 10 lakes in the Tanana River drainage. These lake trout came from eggs taken in September 1990 from Paxson Lake and reared in Clear Hatchery. The number of lake trout stocked, other species present at time of stocking, and the surface area of each lake is listed in Appendix C. Lake trout which were stocked in the four lakes where lake trout were previously stocked were marked with an adipose fin clip to identify them as members of the 1991 group.

RESULTS

LAKE TROUT ABUNDANCE - GALBRAITH LAKE

The estimated abundance of lake trout > 499 mm FL and larger in Galbraith Lake in June, 1994 was 236 fish (SE =41). Estimated density was 0.6 fish per ha (0.2 LT/acre).

A total of 47 lake trout were caught in the sampling gear during the June sampling period. Most lake trout (69%) were caught in gillnets but a few lake trout were captured in each of the gear types fished (Figure 3, Table 2). In August, 107 lake trout were captured. Nearly all were captured in gillnets. Fifteen lake trout were recaptured from the fish marked in June. All recaptured lake trout were > 499 mm FL or larger. Abundance was calculated for fish > 499 mm and larger only.

Testing of Assumptions

Fishing gear set in the outlet stream and in inlet streams to detect immigration or emmigration to or from the lake did not capture lake trout. This result suggests that changes in abundance of lake trout during the June and August sample periods were at least limited and supports the assumption of a closed population.

To test the hypothesis that the probability of capture was the same for lake trout in the north and south halves of the lake, the proportion of fish captured in the August sampling period with and without marks from June were compared (Appendix D). A significant difference was not found ($\chi^2 = 2.65$, df = 1, P = 0.104) indicating that marked fish mixed with unmarked fish between sampling periods.

Comparison of lengths of recaptured lake trout with those > 499 mm and larger captured during the marking event failed to detect a difference (K-S two sample test; D = 0.1, P = 0.98). Comparison of lengths of fish > 499 mm and larger captured during the June sampling period with those captured during August, showed a difference (K-S two sample test; D = 0.3, P =

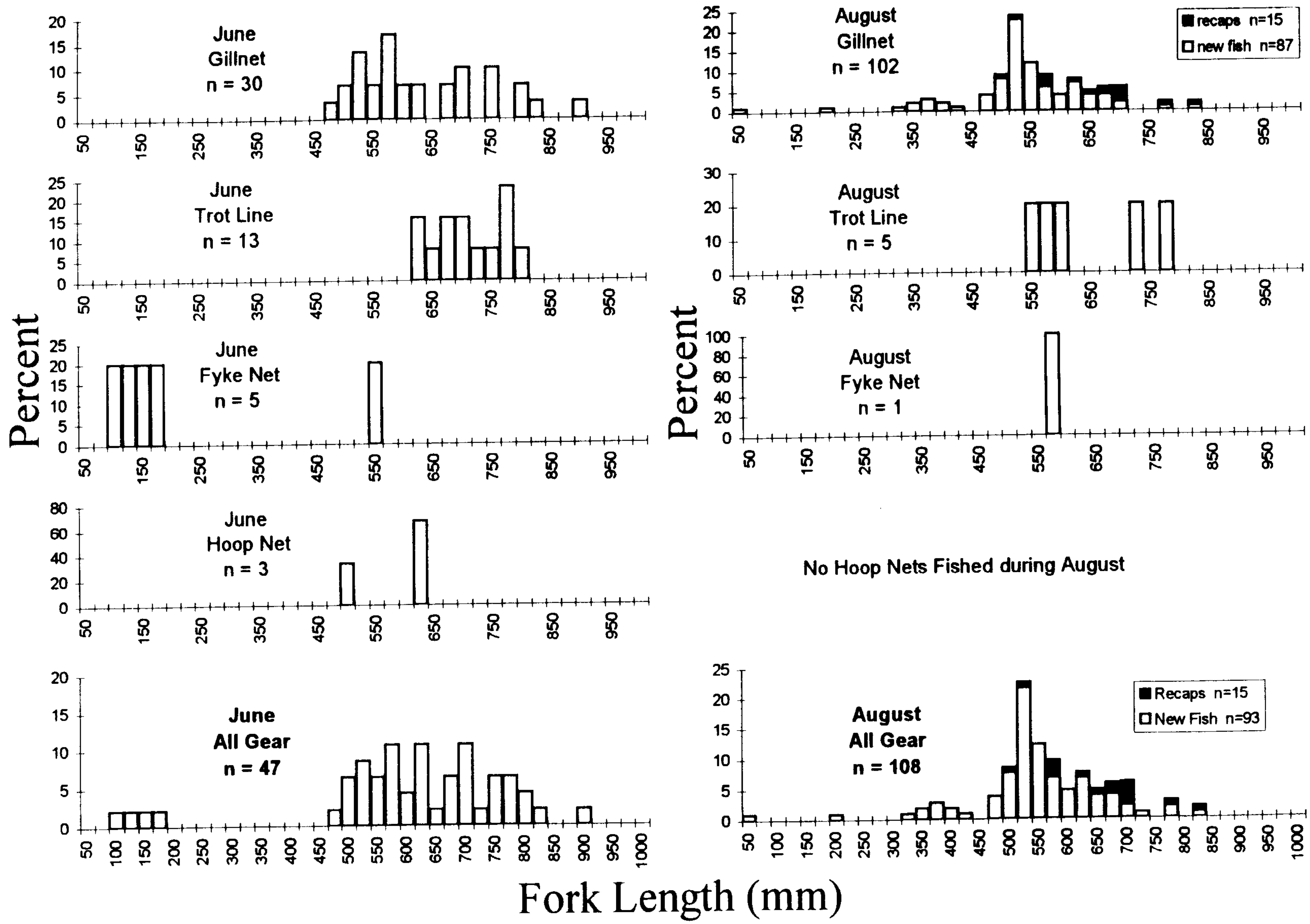

Figure 3.-Lake trout catch by gear type during June and August, Galbraith Lake, 1994.

Table 2.-Number of lake trout captured, marked and recaptured during 1994 at Galbraith Lake to estimate abundance.

	June		August	
Length (mm)	Captured	Marked	Captured	Recaptured
100 - 200	3	0	1	0
450 - 498	2	2	19	0
> 498	42	42	87	15
Total	47	44	107	15

0.02) This indicates size-selectivity in sampling during June but not during August. A single non-stratified estimate was calculated for lake trout > 499 mm and larger.

LENGTH COMPOSITION

Population length composition for lake trout > 499 mm and larger was estimated as the proportion of fish in 25 mm length categories (Figure 4). Because of size selectivity detected in the June sampling, only lengths of fish captured during August were used to calculate length composition.

LAKE TROUT LENGTH DISTRIBUTIONS

Irgnyivik Lake

Between July 12 and 15, 118 lake trout were caught in 32 net sets. Most net sets were approximately 0.5 h in length but poor weather prevented working the nets in a timely manner the first day and fishing time extended to nearly 4 h for a few sets. The CPUE from the Index Fishing was 2.90 lake trout per net hour (Table 3).

Lake trout captured in Irgnyivik Lake ranged from 254 to 711 mm FL with most fish between 300 and 450 mm (Figure 5, Appendix E1). Lake trout sampled were not bimodally distributed; a normal distribution more closely approximates the length frequency observed (see Table 4).

Nanushuk Lake

Between July 15 and 18, 141 lake trout were caught in 36 gillnet sets. The average set time was 0.55 h. The CPUE of lake trout from the Index Fishing was 7.38 fish per net hour (Table 3).

Lake trout captured in Nanushuk Lake ranged from 190 to 441 mm FL with most fish between 300 and 425 mm (Figure 5, Appendix E2). Lake trout sampled were not bimodally distributed; a normal distribution more closely approximates the length frequency observed (see Table 4).

Itkillik Lake

Between July 18 and 20, 66 lake trout were caught in 33 gillnet sets. Most net sets were less than 0.5 h in length; average soak time for all net sets was 0.22 h. Shorter soak times were used due to high catch rates and warm water temperature. The CPUE from the Index Fishing was 9.59 fish per net hour (Table 3).

Lake trout captured in Itkillik Lake ranged from 330 to 803 mm FL with most fish between 375 and 500 mm (Figure 5, Appendix E3). Lake trout sampled were not bimodally distributed; a normal distribution more closely approximates the length frequency observed (see Table 4).

Galbraith Lake

The index sampling method described in Appendix A was used for gillnetting at Galbraith Lake during both the June and August sampling periods. Due to low catch rates, the 30 min set time was increased and averaged 1.7 h per net set during June and 1.2 h per net set during August. The CPUE of lake trout from the Index Fishing was 0.15 fish per net hour in June and 0.31 in August; CPUE was 0.21 lake trout when both sample periods were combined (Table 3, Appendix F1). Lake trout sampled from Galbraith Lake were not bimodally distributed; a normal distribution more closely approximates the length frequency observed (see Table 4).

To increase the number of lake trout captured for the abundance estimate, additional gillnetting was conducted with the "Index" gear during both the June and August sampling periods. In

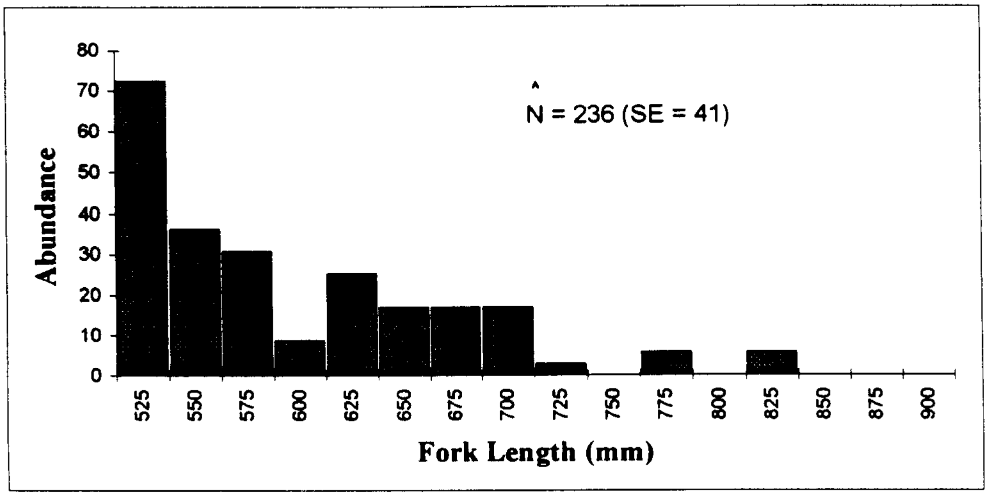

Figure 4.-Estimated length composition of lake trout > 499 mm FL in Galbraith Lake, 1994.

Table 3.-Catch per unit effort from Index Fishing in Irgnyivik, Nanushuk, Itkillik, and Galbraith lakes in 1994.

Lake		Catch by Species					Effort (net hours)	
		RWF	LT	GR	AC	BB		
Irgnyivik Lake								
	CPUE	6.72	2.90	0	0	0	Mean	1.26
	Total	271	118	0	0	0	Total	40
Nanushuk Lake								
	CPUE	0	7.38	0	0	0	Mean	0.55
	Total	0	141	0	0	0	Total	20
Itkillik Lake								
	CPUE	6.16	9.59	0	0	0	Mean	0.22
	Total	45	70	0	0	0	Total	7
Galbraith Lake								
index nets only	CPUE	1.67	0.21	0.03	<0.01	0	Mean	2.9
	Total	571	73	10	1	0	Total	342
Galbraith Lake								
all gillnets	CPUE	1.32	0.25	0.03	<0.01	0	Mean	1.37
	Total	745	135	16	1	0	Total	548

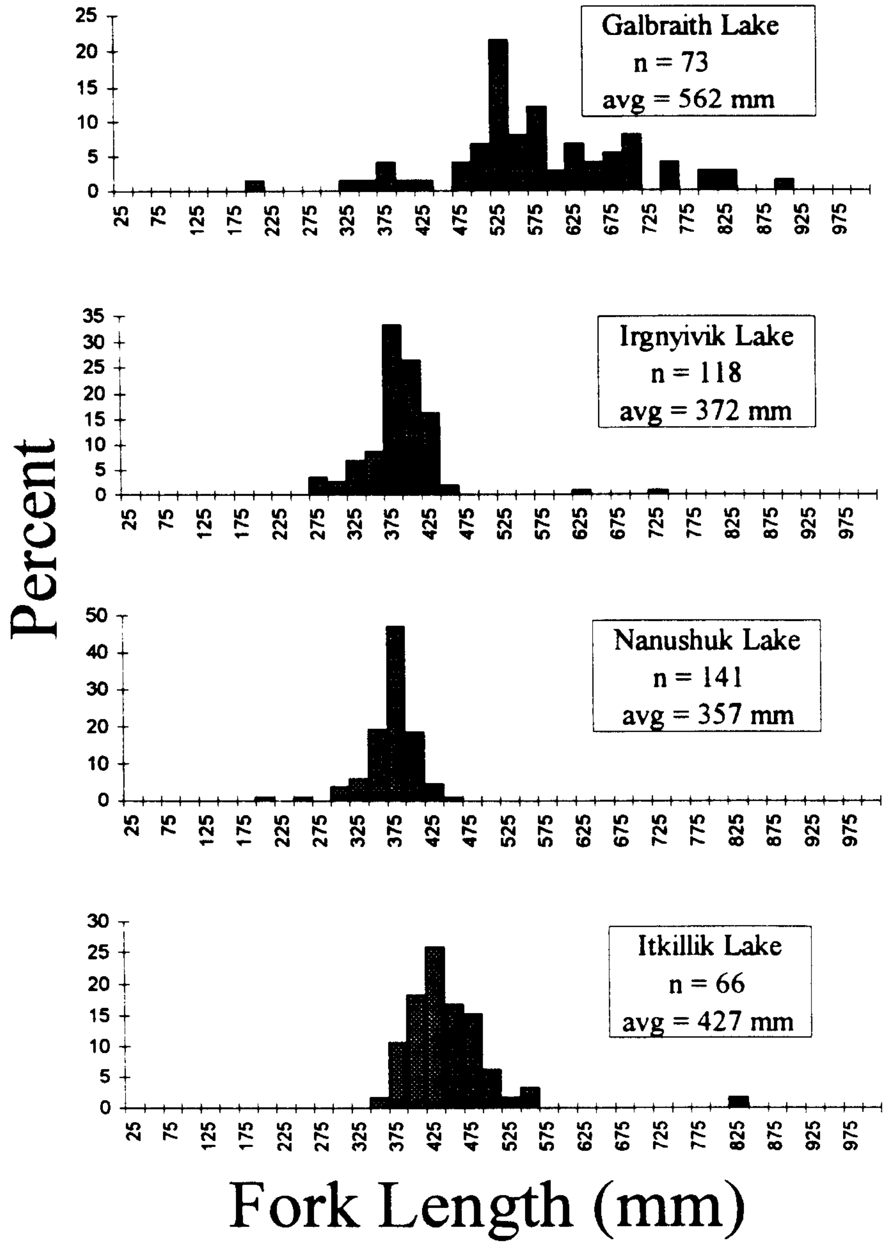

Figure 5.-Length frequencies of lake trout captured during Index Fishing conducted at Galbraith, Irgnyivik, Nanushuk and Itkillik lakes, 1994.

Table 4.-Table of D statistics used to ascribe length distributions.

Lake	Normal	Bimodal	Uniform	Best Fit
Galbraith	0.145	0.427	0.267	Normal
Irgnyivik	0.169	0.510	0.617	Normal
Itkillikh	0.193	0.487	0.613	Normal
Nanushukh	0.170	N/A	0.441	Normal

June, an additional 55 h of gillnetting was conducted. In August, 154 extra hours of gillnetting was conducted using the standard "Index" gear and with multifilament gillnets (Appendix F2).

Selectivity of Index Gillnets

When the catches from all lakes were combined, the pooled sample was 458 lake trout lengths from the three mesh sizes. Sixty six were captured in the 19 mm (0.75 in) mesh, 220 in the 25.5 mm (1.0 in) mesh and 172 in the 32 mm (1.25 in) bar mesh (Figure 6). The hypothesis that the cumulative length distribution of fish caught in the three mesh sizes was the same was rejected ($A2kn = 244.0$, $P < 0.001$). The length distributions of fish caught in the 0.75 and 1.25 inch meshes were not different ($D = 0.1$, $P > 0.05$). In contrast, length distributions of fish caught in the 0.75 mesh were different from the 1.0 inch mesh sample ($D = 0.2$, $P < 0.01$) and length distributions of fish caught in the 1.25 and 1.0 inch meshes were different ($D = 0.2$, $P < 0.0001$).

LIMNOLOGICAL PARAMETERS

Lake area, maximum depth, and mean depth were measured and calculated for the four study lakes; the results are listed in Table 5. Temperature profiles were obtained for Galbraith Lake and for Itkillik Lake (Appendix G). Instrument failure prevented measuring water temperature at depth for Irgnyivik and Nanushuk lakes.

LAKE TROUT YIELD

Estimates of potential yield of lake trout were obtained for the four study lakes and for ten lakes using limnological data collected by LaPerriere and Jones (*unpublished*). The estimates of potential yield both in terms of kg/year and kg/ha/year are listed in Table 5. Potential yield as predicted by the THV model was calculated for only Itkillik Lake of the four study lakes. Temperature profiles are not available for Irgnyivik and Nanushuk lakes. In Galbraith Lake, August water temperature at all depths was above the 12°C limit used to calculate THV.

YEARLING LAKE TROUT IN SEVENMILE LAKE

In spite of 115 sets with minnow traps and 14 small mesh hoop nets baited with salmon eggs and three unbaited fyke nets only one juvenile lake trout was captured. The lake trout was 64 mm FL and weighed 2.8 g. In addition to the lake trout, 36 burbot (57 - 382 mm TL) and 11 slimy sculpin *Cottus cognatus* were caught.

AGE VALIDATION

Samples for the continuing lake trout age validation study were collected. The number of samples collected and the location of collection are listed in Appendix C. These samples together with samples taken in previous years are archived in the Fairbanks office.

DISCUSSION

LAKE TROUT ABUNDANCE - GALBRAITH LAKE

The estimated abundance of lake trout in Galbraith Lake (236 fish 500 mm and larger) was much lower than anticipated. The expected abundance, based on the lake surface area of 412 ha and information from other Alaskan populations (Burr 1992), was about 2,400 lake trout.

A number of factors may be contributing to the perceived low abundance of lake trout in Galbraith Lake. First, the abundance estimate may be in error. The actual number of fish

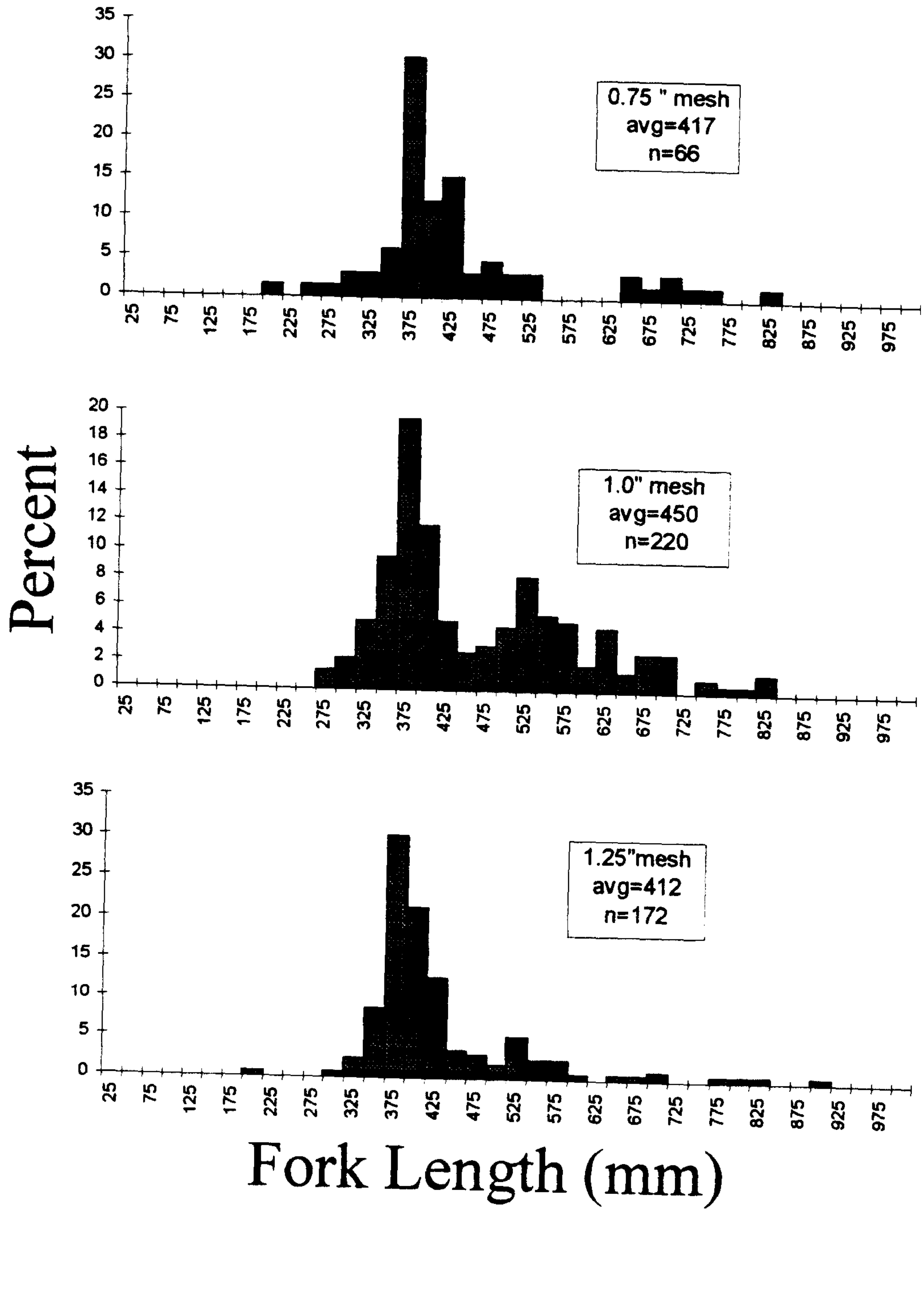

Figure 6.-.Length frequencies of lake trout captured in three mesh sizes during Index Fishing, 1994.

Table 5.-Limnological parameters and estimates of yield of lake trout from 14 lakes in Arctic Alaska.

Lake	Surface Area (ha)	Max Depth (m)	Mean Depth (m)	THV (hm^3)	Yield (THV) kg/yr	Yield (THV) kg/ha/yr	Yield (Area) kg/yr	Yield (Area) kg/ha/yr
Galbraith	410	12.1	4.2	Note[a]	nd	nd	305	0.7
Itkillik	430	13	nd	0.46	81	0.2	315	0.7
Nanushuk[b]	80	58	28	nd	nd	nd	94	1.2
Irgnyivik[b]	90	16.2	5.8	nd	nd	nd	102	1.1
Agrak[b]	150	16	nd	3.10	317	2.1	148	1.0
Amiloyak[b]	100	10	nd	0.16	38	0.4	110	1.1
Chandalar[b]	1,300	22	nd	131.71	4,607	3.5	700	0.5
Kipmik[b]	300	45	nd	11.51	809	2.7	243	0.8
Matcharak[b]	280	25	nd	10.57	761	2.7	231	0.8
Minakakosa[b]	330	54	nd	30.83	1,634	5.0	261	0.8
Narvak[b]	780	114	nd	75.13	3,085	4.0	484	0.6
Selby[b]	1,000	33	15	19.64	1,184	1.2	579	0.6
Takahula[b]	180	55	nd	7.92	619	3.4	168	0.9
Walker[b]	3,800	122	61	139.98	4,812	1.3	1,517	0.4

[a] Water at all depths warmer than 12°C on August 6, 1995.

[b] *Unpublished data* J. LaPerriere and Jones.

handled during the experiment was low. The estimator is potentially unreliable with low sample size. It is also possible that immigration or emmigration occurred in the hiatus between sampling in June and August. However the high proportion of marked fish present in the August sample argues against movement of fish into or out of the lake. Given the high level of sampling effort expended during almost a month of the 2.5 to 3 month open water period, it seems reasonable to assume that the samples collected were representative and the abundance of lake trout during the summer period was accurately estimated.

Low abundance may be the result of limited suitable habitat. Most lake trout lakes are characterized by cold, clear, well oxygenated water and by extensive rubble/cobble shoals needed for spawning. Water temperatures measured during August at Galbraith Lake were above the optimal range described for lake trout inhabiting lakes in Ontario (Payne et al. 1990). The shoreline is composed in places of large angular rocks but is generally overlain with mud and silt. The lake substrate at depths greater than 1 m is almost entirely mud and silt.

Lake trout may emmigrate from the lake during the open water period to reside in the Atigun River. Sampling conducted in the outlet stream failed to capture lake trout. However, sampling did not begin until mid June and the outlet stream had been flowing for more than a week. The amount of suitable habitat available in the Atigun River would appear to be very limited and it is unlikely that a large portion of the Galbraith population spends the open water season in the river. In any event, most sport fishing effort directed at lake trout in Galbraith Lake likely occurs during the summer period.

Low abundance of lake trout may be the result of sport fishing effort. During early road and oil pipeline construction, a large camp was located near the shore of Galbraith Lake. Sport fishing was closed within the pipeline corridor in the mid 1970's but not until significant harvest is believed to have occurred at Galbraith Lake and other area lakes. Following completion of the oil pipeline, sport fishing for most species was reopened in 1979. Less than a dozen lakes located within the Dalton Highway corridor contain lake trout. Between 1986 and 1993 estimated harvest of lake trout within the corridor averaged 95 fish (Mills 1994). More significantly, 5 to 100% of the harvest of lake trout for the entire north slope area came from Dalton Highway waters.

LENGTH COMPOSITION

The estimate of abundance and of length composition of lake trout in Galbraith Lake was only for fish larger than 499 mm FL. This is because very few fish less than that size were captured. The reason for the absence of smaller sized lake trout in the samples is unknown. All areas of the lake were sampled and work in other area lakes demonstrated that smaller lake trout should have been caught in the sampling gear. During August, special effort was directed at sampling the streams and small connected lakes to determine if significant numbers of lake trout smaller than 500 mm were using these alternative habitats; no lake trout were caught. In absence of better information, it must be assumed that the abundance of juvenile lake trout in this population is very low.

LAKE TROUT LENGTH DISTRIBUTIONS

Catches of fish from multiple mesh gillnets do not necessarily provide representative samples from which to estimate length composition (Hamley 1975, Power 1978). Smaller size classes in particular (FL < 250 mm) are unlikely to be represented in proportion to their abundance.

In Itkillik Lake, where total gillnetting effort was less, less abundant length groups are unlikely to be fully represented in the sample.

Catches of lake trout from unexploited populations have been described as having a bimodal length distribution (Johnson 1976, Power 1978) with abundant large fish > 750 mm and abundant small fish < 650 mm with very few lake trout of lengths in between. With exploitation, larger older lake trout are typically removed, a change in the mortality pattern occurs, and the bimodal length frequency distribution disappears. A bimodal distribution was not observed in the samples from any of the populations studied. If a representative sample is assumed, the absence of the bimodal pattern may be taken as evidence that significant exploitation has occurred in the sampled lakes.

An alternative explanation to exploitation can be offered for the absence of a bimodal pattern in lengths. Evans et al. 1991 reports that the maximum length attained by lake trout varied directly with Lake Area such that large lake trout were found only in large lakes. An important factor in attaining large size appears to be the availability of increasingly larger prey as the lake trout grow (Carl et al. 1990). The absence of fish species other than lake trout is likely partially responsible for the absence of larger fish in Nanushuk Lake. Round whitefish are available as prey in Irgnyivik Lake but the mean size of lake trout in Irgnyivik Lake is small. Only in Itkillik and Galbraith lakes, which have greater surface area and where prey species are found, had substantial proportions of larger fish observed in the samples.

Irgnyivik and Nanushuk lakes are believed to be relatively unexploited due to their more remote location. Itkillik Lake, while removed from the road is likely to have received more fishing pressure. The lake is used as a staging area by recreational hikers, river floaters and sheep hunters. The low proportion of larger lake trout in the Itkillik Lake sample may be a result of lower sampling effort. In future netting efforts, care should be taken to standardize not only the number of sets but also the total duration of netting effort. More detailed assessment of the remote lakes should be conducted to clarify the relationship between the length distributions of fish captured with Index Fishing and the status of the populations.

Galbraith Lake which has been subjected to the greatest amount of fishing pressure in the study area also appears to have the greatest proportion of large lake trout. While anglers may have changed the relative proportion of fish in large size (and age) groups, a substantial proportion of this small population is composed of adult-sized individuals presumably capable of reproduction. The nearly complete absence of sub-adult lake trout in Galbraith Lake suggests that recruitment in this population is limited but the reason for the poor recruitment is unknown.

CPUE OF LAKE TROUT CAPTURED WITH INDEX FISHING

Catch rates varied widely between the lake trout populations sampled. Three of the lakes sampled in 1994 were characterized by relatively high catch rates: Irgnyivik Lake, 2.9 fish/ hr, Nanushuk Lake 7.4 fish/hr, and Itkillik Lake 9.6 fish/hr. The catch rate from sampling conducted at Galbraith Lake was dramatically less; 0.21 fish/hr. Island Lake was sampled in 1989 (Burr 1990) with similar gear but net sites were selected with the goal of maximizing catch. At Island Lake, 217 gillnet hours caught 34 lake trout or 0.16 fish/hr. The low catch rates found in Galbraith and Island lakes are indicative of low population abundance. In absence of better information CPUE from Index Fishing may provide an index of abundance.

Experiments to estimate population abundance in the high CPUE lakes would aid in development of this tool.

Galbraith and Island lakes are located within the Haul Road corridor; the other three lakes are accessed by float plane (15 to 40 min flights from Toolik Lake). The catch rates for lake trout from the lakes directly accessed from the Haul Road were much lower than from lakes accessed by floatplane. This information together with the low abundance of lake trout in Galbraith Lake and studies conducted on the Toolik Lake population resulted in the closure of lakes within the Haul Road corridor to the harvest of lake trout.

LAKE TROUT YIELD

Potential yield of lake trout was predicted from both the THV and the Lake Area models developed in Ontario. Except for Itkillik and Amiloyak lakes the potential yield of lake trout as predicted by the THV model was greater than predicted from Lake Area (Table 4). These two lakes are characterized as generally shallow; areas where cool water is found in deeper basins are very limited.

A potential difficulty with use of the THV model is that the model assumes that water temperature is a major limiting element of habitat. In Arctic lakes, hard thermal stratification is rare (J. LaPerriere, ACFRU, University of Alaska Fairbanks, personal communication). Thermal stratification is ephemeral due to wind mixing and because of dramatic short term changes in air temperature. In these Arctic lakes critical elements of habitat other than the temperature regime are likely to be limiting. The Lake Area model incorporates a large number of biotic and habitat elements and is therefore likely more appropriate for lake trout lakes in this region.

The potential yield of lake trout predicted from these models should be viewed as maximum potential yield. The lakes in Ontario from which the estimators were developed are likely to be more productive than lakes in Alaska.

YEARLING LAKE TROUT IN SEVENMILE LAKE

The very poor catch of yearling lake trout during sampling conducted in September was unexpected. In past netting efforts (primarily fyke nets) at Sevenmile Lake juvenile lake trout were frequently captured. For example, during sampling conducted in July 1987 , 35 lake trout varying in length from 47 to 99 mm FL were captured. Most sampling with gear types appropriate for capturing small lake trout has been conducted during June and July. It is possible that the juvenile lake trout are not as available to the gear during the September period. Sampling effort should be directed at capturing juvenile lake trout during July 1995.

An alternative method of accessing the effect of removing fertilized eggs from the Sevenmile Lake population will needed if sampling efforts in 1995 fail to provide the needed samples of juvenile lake trout. Failure to meet the modest goal of capturing 50 juvenile lake trout may be indicative of a severe effect on recruitment to this small lake trout population.

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APPENDIX A
Burbot Index of Abundance in Galbraith Lake

INTRODUCTION

Burbot are pursued by anglers because they are readily harvested with unattended set lines and because of the fish's excellent table qualities. Anecdotal reports indicate that "jug fishing" and shoreline set lines were used extensively in Galbraith Lake during road construction (1970's) and later with reopening of the Haul Road corridor to sport fishing (1979-present). Sampling methodologies were developed which use catches of burbot in hoop nets as an index of abundance (Bernard et al. 1991). Information in Bernard et al. 1993 can be used to turn the index of abundance into an estimate of abundance (see Taube et al. 1994). Stock assessment sampling for lake trout conducted at Galbraith Lake provided the opportunity to assess the burbot population at little additional cost.

METHODS

An estimate of mean CPUE of burbot caught in 48 h sets with hoop nets (Bernard et al. 1991) was used as an index of abundance. Mean CPUE was calculated for all burbot >299 mm TL (size of retention in the hoop nets). The location of hoop net sets was chosen systematically to ease finding the locations on the lakes. First, an overlay with parallel lines was placed across a map of the lake at a randomly chosen position but with the lines in the overlay perpendicular to the long axis of the lake. Distances between adjacent lines in the overlay represent 125 m[1]. Each parallel line has tic marks that represent a distance of 125 m. Next, the desired number of sets were compared with the tic marks that are over the water on the map; parallel lines were randomly excluded until the tic marks and the desired number of sets were the same. Traps were set in transects corresponding to the position of each remaining parallel line. The location of the first set along each transect was randomly chosen with every subsequent set along that transect at 125 m. Burbot captured in deeper water survive at lower rates after their release than do burbot captured in shallower water (Bernard et al. 1993). Hence, sets are generally not made at depths greater than 15 m. The maximum recorded depth at Galbraith Lake is 7 m (23 ft) so sets in this lake were located without regard to depth.

Burbot were captured in hoop traps. Each trap is 3.095 m long with seven 6.35 mm steel hoops. Hoop diameter tapers from 0.61 m at the entrance to 0.46 m at the cod end. Each trap has a double throat (tied to the first and third hoops) which narrows to 0.31 m (flattened). All netting is 25 mm (bar measure) treated with asphaltic compound. The trap is kept stretched with two 2.15 m long sections of 12 mm diameter galvanized steel conduit attached with snap clips at the end hoops. A numbered buoy is attached to the end of the trap with rope. Each trap is baited with herring placed in a 500 ml perforated plastic container. Bait containers are placed unattached in the cod end.

Each hoop trap was fished for 48 h (a set). This set time has been shown to maximize the catch of burbot per set in lakes (Bernard et al. 1991). Upon capture, each burbot was measured to the nearest millimeter of total length, marked with an individually numbered Floy anchor tag and a left pectoral fin clip, and returned to the lake. Any burbot showing signs of

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[1] The distance between traps of 125 m was selected to eliminate gear competition. The effective fishing area of a baited trap was estimated to be 0.45 ha by dividing the average CPUE for burbot caught per ha from a mark-recapture experiment conducted in Fielding Lake in 1985 (Bernard et al. 1991). This estimated fishing area was arbitrarily increased to one ha to ensure elimination of gear competition; this area corresponds to traps set at a distance of about 125 m. Similar calculations from data collected in 1987 support this distance as being sufficient to eliminate gear competition.

stress at capture were held in net pens. All fish killed were dissected to obtain otoliths for age determination.

Methods for calculating CPUE, catchability coefficient, density, and abundance are described in Lafferty et al. 1992.

RESULTS

The observed CPUE for fully recruited burbot was 0.216 fish per hoop net set (Table A1). Because only small hoop traps which are size-selective against larger burbot were used, a correction factor of 1.8 was used (Bernard et al 1991) and the estimated CPUE was 0.216. Between June 21-25, 32 burbot were captured in 150 hoop net sets placed along 18 transects. Burbot less than 450 mm are not fully recruited to this sampling gear; 19 of the burbot caught in hoop nets were 450 mm and larger.

Burbot were also caught in other fishing gear during the June and August sampling period. Twenty-seven burbot were caught in minnow traps, 47 in fyke nets, 11 in hookless jugs and 1 in a gillnet for a total of 112 unique fish (Table A2). Six of the 11 burbot caught on the hookless jugs were caught more than once on this gear type.

DISCUSSION

The CPUE of burbot with standardized hoop net gear was low. The result from Galbraith Lake is similar to the result from Summit Lake (Gulkana River) where CPUE was 0.17 and 0.19 during June and September, 1987 (Lafferty et al. 1992). The estimated density of burbot in Summit Lake at that time was 0.363. By substituting the estimated density of burbot from Summit Lake, a rough estimate of abundance of burbot in Galbraith Lake can be calculated. This estimate is 150 burbot 450 mm and larger.

Low abundance of burbot in Galbraith Lake is likely the result of two factors. The first is exploitation by fishermen. At least two dozen jugs and floats rigged with line and hooks were found washed up on the lake shore. This indicates that jug fishing which was common in the 1970's has continued to occur. This type of fishing can have a large impact on lake fish resources because it selects for large burbot and large lake trout. The catch of lake trout and burbot with the hookless jugs demonstrates the effectiveness of this gear type.

The second factor which may have affected the number of burbot caught in Galbraith Lake is emmigration from the lake through the inlets and outlets. Burbot are known to reside in the Atigun River during the open water period. The burbot presumably overwinter in adjacent lakes (e.g. Galbraith) and in deep holes in the river. Winters (1992) caught and marked burbot in the Atigun River during August 1991. One of the burbot which he captured near the mouth of the outlet creek (620 mm in 1991) was recaptured in the lake in June (690 mm in 1994).

Appendix A1.-Estimated CPUE and abundance of fully recruited burbot (>450 mm TL) from Index Fishing at Galbraith Lake, 1994

Date	Surface Area (ha)	Estimated CPUE[a]	Estimated Density[b]	Catchability Coefficient[c]	Estimated Abundance[d]
June 21-26	412	0.216	0.363	0.0336	150

[a] Estimated CPUE = Observed CPUE * correction factor for gear selectivity (1.8) because only small hoop traps were used (Bernard et al 1991).

[b] Density of Summit Lake burbot used (CPUE estimate from Summit Lake of 0.169 similar to Galbraith Lake, data from Lafferty et al. 1992)

[c] Catchability Coefficient (CC) is CPUE/DENSITY

[d] Abundance from ad hoc method: N = CPUE * AREA * 1/CC

Appendix A2.-Burbot captured in various gear types in Galbraith Lake, 1994.

Upper	Hoop Net			Minnow Trap			Fyke Net			Jug Line			Gillnet		All Gear		
Length	n	%	SE	n	%	SE	n	%	SE	n	%	SE	n	%	n	%	SE
49	0	0	0.00	0	0	0.00	0	0	0.04	0	0	0.00	0	0	0	0	0.02
74	0	0	0.00	0	0	0.00	3	6	0.06	0	0	0.00	0	0	3	3	0.03
99	0	0	0.00	0	0	0.04	10	21	0.05	0	0	0.00	0	0	10	9	0.02
124	0	0	0.00	1	4	0.04	5	11	0.04	0	0	0.00	0	0	6	5	0.02
149	0	0	0.00	1	4	0.00	4	9	0.03	0	0	0.00	0	0	5	4	0.01
174	0	0	0.00	0	0	0.00	2	4	0.00	0	0	0.00	0	0	2	2	0.00
199	0	0	0.00	0	0	0.00	0	0	0.02	0	0	0.00	0	0	0	0	0.01
224	0	0	0.00	0	0	0.00	1	2	0.02	0	0	0.00	0	0	1	1	0.01
249	0	0	0.03	0	0	0.00	1	2	0.02	0	0	0.00	0	0	1	1	0.01
274	1	3	0.00	0	0	0.04	1	2	0.00	0	0	0.00	0	0	2	2	0.01
299	0	0	0.03	1	4	0.06	0	0	0.00	0	0	0.00	0	0	1	1	0.02
324	1	3	0.05	3	11	0.06	0	0	0.02	0	0	0.00	1	100	4	4	0.02
349	3	9	0.05	3	11	0.00	1	2	0.02	0	0	0.00	0	0	7	6	0.02
374	3	9	0.00	0	0	0.05	1	2	0.03	0	0	0.00	0	0	4	4	0.02
399	0	0	0.06	2	7	0.05	2	4	0.02	0	0	0.00	0	0	4	4	0.02
424	4	13	0.03	2	7	0.05	1	2	0.04	0	0	0.00	0	0	8	7	0.02
449	1	3	0.06	2	7	0.06	4	9	0.02	0	0	0.00	0	0	7	6	0.02
474	4	13	0.04	3	11	0.04	1	2	0.03	0	0	0.09	0	0	8	7	0.02
499	2	6	0.03	1	4	0.04	2	4	0.00	1	9	0.09	0	0	6	5	0.01
524	1	3	0.04	1	4	0.04	0	0	0.03	1	9	0.00	0	0	2	2	0.02
549	2	6	0.00	1	4	0.00	2	4	0.00	0	0	0.00	0	0	5	4	0.00
574	0	0	0.04	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0	0	0.01
599	2	6	0.04	0	0	0.04	0	0	0.03	0	0	0.12	0	0	2	2	0.02
624	2	6	0.03	1	4	0.04	2	4	0.02	2	18	0.09	0	0	7	6	0.01
649	1	3	0.00	1	4	0.00	1	2	0.02	1	9	0.09	0	0	2	2	0.01
674	0	0	0.00	0	0	0.00	1	2	0.00	1	9	0.00	0	0	2	2	0.00
699	0	0	0.00	0	0	0.06	0	0	0.02	0	0	0.12	0	0	0	0	0.02
724	0	0	0.03	3	11	0.00	1	2	0.02	2	18	0.09	0	0	5	4	0.02
749	1	3	0.00	0	0	0.00	1	2	0.00	1	9	0.00	0	0	3	3	0.00
774	0	0	0.03	0	0	0.04	0	0	0.00	0	0	0.09	0	0	0	0	0.01
799	1	3	0.04	1	4	0.00	0	0	0.00	1	9	0.09	0	0	2	2	0.01
824	2	6	0.03	0	0	0.00	0	0	0.00	1	9	0.00	0	0	2	2	0.01
849	1	3	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0	0	1	1	0.00
874	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0	0	0.00
899	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0	0	0.00
Total	32			27			47			11			1		112		
Mean	503			445			283			660			302		402		
SE	157			167			211			102			0		210		
Min	270			114			65			499					65		
Max	830			776			735			800					830		

APPENDIX B
Index Fishing

Appendix B.-Index Fishing.

Fishing Gear

Gear used was a 46 m (150 ft) gillnet gang, comprised of three 15.2 m (50 ft) panels. All three panels are of the same mesh size, either 19 mm (.75 in), 25.5 mm (1.0 in), or 32 mm (1.25 in) bar mesh. The panels are 2.4 m (8 ft) tall. The mesh is made of monofilament and dyed green.

Sampling Methods

The sampling occurred during daylight hours after ice melt and before surface temperature reached 13^{o} C. Ten sample days were needed for Galbraith Lake and three sample days for Nanushuk, Irgnyvik, and Itkillik lakes (index lakes). In each case, sample days were randomly selected from expected available days and several randomly selected sites were sampled for 30 min each day. Twelve 12 sites per day were sampled and the following procedure was used for selecting sample sites:

1. partition the shoreline into 120 equal length sections;
2. for each sample day, randomly select 12 sections without replacement;
3. determine the optimum survey path (least distance) for visiting the 12 sections (sampled on one day) and set one gillnet gang in each section; and,
4. set gangs of different mesh in sequence (i.e. 38 mm at site 1, 51 mm at site 2, 64 mm at site 3, 38 mm at site 4, 51 mm at site 5, etc.) so that different mesh sizes are distributed throughout the lake and four sites are sampled by each mesh per day.

Gangs were set perpendicular to the shoreline starting at a depth of 2.5 m or less and extended no deeper than 30 m. The starting location was random within the section sampled, with the exception that river mouths, debris strewn areas (likely to damage nets) and very steep gradients (> 45^{o}) were avoided.

The nets were left to fish for 30 min and the following data are obtained from each set:

1. the total number of fish captured (by species);
2. fork length (total length for burbot), and scale sample from each fish;
3. otolith and sex from dead lake trout, Arctic char, and burbot; and,
4. a record of fin clips, tags and other marks.

APPENDIX C
Lake Trout Age Validation Study

Appendix C.-Lake trout age validation study.

Stocked lake trout have provided fish of known age from which validation of age determination will be investigated. Lakes which contain lake trout of known age are listed in the following table. The age of these fish is known because either the water body was stocked only once or fin clips were used to differentiate between stocking cohorts. Starting in 1992, lake trout were sampled and the age structures archived from the 1991 stocking cohort. It is estimated that less than 100 samples will be needed annually from this cohort. These data will be collected for at least five consecutive years after which analysis and evaluation of these data will be conducted.

			Number Sampled		
Lake	Date Stocked	Fin Clip	1992	1993	1994
Bullwinkle	1989	None	1	0	0
Chet	1991	Adipose	0	0	9
Coal Mine #5	1991	Adipose	10	0	9
Craig	1991	None	5	0	0
Fourmile	1991	None	0	0	0
Fourteenmile	1991	None	25	14	0
Nickel	1991	Adipose	10	1	8
North Twin	1991	None	18	6	0
Paul's Pond	1991	Adipose	4	0	0
Rapids	1991	None	7	16	10
Summit	1989	None	2	0	0

To determine if the ages obtained from otoliths, opercular bones, and scales are true ages, the proportion (and variance) of lake trout whose estimated age reflects the true age will be calculated for each structure as:

$$\hat{p} = \frac{a}{n}$$

$$V[\hat{p}] = \frac{\hat{p}(1-\hat{p})}{n-1}$$

where:

a = the number of fish whose assigned ages agree with the true age; and,

n = total number of known age structures in the sample.

A one-tailed Z test (Zar 1984) will be performed to determine if the accuracy rate for any one structure is significantly less than 0.90.

Appendix C.-Page 2 of 2.

H_o: $P = 0.90$

H_a: $P < 0.90$

The test will have the ability to detect a 10% difference with the probabilities of an experiment-wise type I error being 0.05 and the probability of a type II error being 0.20.

Contingency table analysis will be used to determine if all structures are equally accurate by testing the hypothesis:

H_o: accuracy is independent of structure

H_a: accuracy is dependent on structure.

To determine if the estimated ages for any of the structures is different, the mean ages determined for each structure will be compared using analysis of variance with structures as fixed effects. Multiple comparisons will be made using Fisher's Least Significant Difference test. The hypothesis that will be tested is:

Ho: μ scales = μ otoliths = μ opercular

Ha: at least one is not equal.

Logistic regression will be used to determine if the accuracy in determining the age of lake trout decreases as the true age increases:

H_o: $\beta = 0$

H_a: $\beta < 0$.

APPENDIX D

Appendix D.-Number of marked and unmarked lake trout captured by area in Galbraith Lake, August, 1994.

	Number of lake trout captured		
Area	With Marks	Without Marks	Prop w/ Marks
North	8	68	0.11
South	7	24	0.23
Total	15	92	0.14

$\chi^2 = 2.65$ [a], df = 1, $0.05 < P < 0.10$

[a] The χ^2 value is the test statistic for the hypothesis of equal probability of capturing marked fish in either half of the lake.

APPENDIX E

Appendix E1.-Lengths of lake trout captured by gear type from Irgnyivik Lake, 1994.

	3/4"		1"		1 1/4"		All				All	
Upper	Gillnet		Gillnet		Gillnet		Gillnet		Hoop Net		Gear	
Length	n	%	n	%	n	%			n	%	n	%
250	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
275	1	2.9	3	6.8	0	0.0	4	3.4	0	0.0	4	3.2
300	1	2.9	2	4.5	0	0.0	3	2.5	1	12.5	4	3.2
325	1	2.9	5	11.4	2	5.0	8	6.8	0	0.0	8	6.3
350	4	11.8	3	6.8	3	7.5	10	8.5	1	12.5	11	8.7
375	9	26.5	15	34.1	15	37.5	39	33.1	1	12.5	40	31.7
400	7	20.6	11	25.0	13	32.5	31	26.3	3	37.5	34	27.0
425	9	26.5	4	9.1	6	15.0	19	16.1	1	12.5	20	15.9
450	1	2.9	0	0.0	1	2.5	2	1.7	1	12.5	3	2.4
475	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
500	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
525	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
550	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
575	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
600	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
625	0	0.0	1	2.3	0	0.0	1	0.8	0	0.0	1	0.8
650	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
675	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
700	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
725	1	2.9	0	0.0	0	0.0	1	0.8	0	0.0	1	0.8
750	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
775	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
800	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
825	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
850	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
875	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
900	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	34		44		40		118		8		126	
Mean	381		360		377		372		374		372	
SE	70		56		27		53		47		53	
Min	254		255		307		254		279		254	
Max	711		610		445		711		426		711	

Appendix E2.-Lengths of lake trout captured by gear type from Nanushuk Lake, 1994.

Upper Length	3/4" Gillnet n	3/4" Gillnet %	1" Gillnet n	1" Gillnet %	1 1/4" Gillnet n	1 1/4" Gillnet %	All Gillnet n	All Gillnet %	Minnow Net n	Minnow Net %	Sport Gear n	Sport Gear %	All Gear n	All Gear %
200	1	6	0	0	0	0	1	1	0	0	0	0	1	1
225	0	0	0	0	0	0	0	0	0	0	0	0	0	0
250	1	6	0	0	0	0	1	1	0	0	1	33	2	1
275	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	1	6	3	5	1	2	5	4	0	0	0	0	5	3
325	1	6	5	8	2	3	8	6	0	0	0	0	8	5
350	0	0	15	25	12	18	27	19	0	0	0	0	27	18
375	11	65	23	39	32	49	66	47	2	100	0	0	68	47
400	1	6	10	17	15	23	26	18	0	0	0	0	26	18
425	0	0	3	5	3	5	6	4	0	0	1	33	7	5
450	1	6	0	0	0	0	1	1	0	0	0	0	1	1
475	0	0	0	0	0	0	0	0	0	0	0	0	0	0
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0
525	0	0	0	0	0	0	0	0	0	0	1	33	1	1
550	0	0	0	0	0	0	0	0	0	0	0	0	0	0
575	0	0	0	0	0	0	0	0	0	0	0	0	0	0
600	0	0	0	0	0	0	0	0	0	0	0	0	0	0
625	0	0	0	0	0	0	0	0	0	0	0	0	0	0
650	0	0	0	0	0	0	0	0	0	0	0	0	0	0
675	0	0	0	0	0	0	0	0	0	0	0	0	0	0
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0
725	0	0	0	0	0	0	0	0	0	0	0	0	0	0
750	0	0	0	0	0	0	0	0	0	0	0	0	0	0
775	0	0	0	0	0	0	0	0	0	0	0	0	0	0
800	0	0	0	0	0	0	0	0	0	0	0	0	0	0
825	0	0	0	0	0	0	0	0	0	0	0	0	0	0
850	0	0	0	0	0	0	0	0	0	0	0	0	0	0
875	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	17		59		65		141		2		3		146	
Mean	345		354		363		357		359		391		358	
SE	59		28		21		31		2		149		36	
Min	190		282		297		190		357		229		190	
Max	441		409		418		441		360		523		523	

Appendix E3.-Lengths of lake trout captured by gear type from Itkillik Lake, 1994.

Upper Length	3/4" Gillnet n	3/4" Gillnet %	1" Gillnet n	1" Gillnet %	1 1/4" Gillnet n	1 1/4" Gillnet %	All Gillnet n	All Gillnet %	Minnow Net n	Minnow Net %	Sport Gear n	Sport Gear %	All Gear n	All Gear %
250	0	0	0	0	0	0	0	0	0	0	0	0	0	0
275	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0
325	0	0	0	0	0	0	0	0	0	0	0	0	0	0
350	0	0	1	4	0	0	1	2	0	0	0	0	1	1
375	0	0	3	13	4	10	7	11	0	0	2	15	7	10
400	0	0	4	17	8	21	12	18	0	0	4	31	12	18
425	1	25	3	13	13	33	17	26	0	0	3	23	17	25
450	0	0	6	26	5	13	11	17	0	0	4	31	11	16
475	2	50	3	13	5	13	10	15	0	0	0	0	10	15
500	1	25	2	9	1	3	4	6	0	0	0	0	4	6
525	0	0	0	0	1	3	1	2	0	0	0	0	1	1
550	0	0	0	0	2	5	2	3	0	0	0	0	2	3
575	0	0	0	0	0	0	0	0	1	100	0	0	1	1
600	0	0	0	0	0	0	0	0	0	0	0	0	0	0
625	0	0	0	0	0	0	0	0	0	0	0	0	0	0
650	0	0	0	0	0	0	0	0	0	0	0	0	0	0
675	0	0	0	0	0	0	0	0	0	0	0	0	0	0
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0
725	0	0	0	0	0	0	0	0	0	0	0	0	0	0
750	0	0	0	0	0	0	0	0	0	0	0	0	0	0
775	0	0	0	0	0	0	0	0	0	0	0	0	0	0
800	0	0	0	0	0	0	0	0	0	0	0	0	0	0
825	0	0	1	4	0	0	1	2	0	0	0	0	1	1
850	0	0	0	0	0	0	0	0	0	0	0	0	0	0
875	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	4		23		39		66		1		13		67	
Mean	458		431		422		427		550		400		429	
SE	29		91		44		64				27		65	
Min	422		330		350		330				362		330	
Max	494		803		547		803				437		803	

APPENDIX F

Appendix F1.-Catch and effort from Index Fishing conducted in Galbraith Lake during June and August, 1994.

Mesh Size/ Sample Period		Catch by Species RWF	LT	GR	AC	BB	Effort (hours)	
All Gillnets								
Both	CPUE	1.67	0.21	0.03	0	0	Mean	2.85
	Total	571	73	10	0	0	Total	342.40
June	CPUE	1.26	0.15	0.01	0	0	Mean	1.66
	Total	249	29	2	0	0	Total	199.65
August	CPUE	2.26	0.31	0.06	0	0	Mean	1.19
	Total	322	44	8	0	0	Total	142.75
0.75 in. mesh								
Both	CPUE	1.21	0.10	0	0	0	Mean	1.44
	Total	140	11	0	0	0	Total	115.55
June	CPUE	0.75	0.06	0	0	0	Mean	1.63
	Total	49	4	0	0	0	Total	65.05
August	CPUE	1.80	0.14	0	0	0	Mean	1.26
	Total	91	7	0	0	0	Total	50.50
1.0 in. mesh								
Both	CPUE	2.14	0.35	0.06	0	0	Mean	1.43
	Total	245	40	7	0	0	Total	114.35
June	CPUE	1.91	0.25	0.03	0	0	Mean	1.71
	Total	130	17	2	0	0	Total	68.20
August	CPUE	2.49	0.50	0.11	0	0	Mean	1.15
	Total	115	23	5	0	0	Total	46.15
1.25 in. mesh								
Both	CPUE	1.65	0.20	0.03	0	0	Mean	1.41
	Total	186	22	3	0	0	Total	112.50
June	CPUE	1.05	0.12	0	0	0	Mean	1.66
	Total	70	8	0	0	0	Total	66.40
August	CPUE	2.52	0.30	0.07	0	0	Mean	1.15
	Total	116	14	3	0	0	Total	46.10

Appendix F2.-Gillnet effort in excess of Index Fishing conducted at Galbraith Lake, 1994.

Sample Period	Gear		Effort (hours)		Catch LT	RWF	GR	BB	AC
June	gear A	Total	8	Total	0	6	0	0	0
		mean	2.1	CPUE	0.00	0.73	0.00	0.00	0.00
	gear B	Total	24	Total	1	27	4	0	0
		mean	1.8	CPUE	0.04	1.13	0.17	0.00	0.00
	gear C	Total	23	Total	0	20	0	0	0
		mean	2.3	CPUE	0.00	0.88	0.00	0.00	0.00
	All	Total	55	Total	1	53	4	0	0
		mean	2.0	CPUE	0.02	0.96	0.07	0.00	0.00
August	gear A	Total	8	Total	6	7	0	0	0
		mean	1.0	CPUE	0.73	0.85	0.00	0.00	0.00
	gear B	Total	83	Total	30	30	2	0	0
		mean	1.1	CPUE	0.36	0.36	0.02	0.00	0.00
	gear C	Total	19	Total	3	35	0	0	1
		mean	1.1	CPUE	0.16	1.82	0.00	0.00	0.05
	gear D	Total	43	Total	25	51	0	0	0
		mean	1.2	CPUE	0.58	1.19	0.00	0.00	0.00
	All	Total	154	Total	64	123	2	0	1
		mean	1.1	CPUE	0.42	0.80	0.01	0.00	0.01

Gear A = 0.75 monofilament gillnet, gear B = 1.0 monofilament gillnet, gear C = 1.25 monofilament gillnet, gear D = 1.0 multifilament gillnet.

APPENDIX G

Appendix G.-Water temperature (°C) from Galbraith, Irgnyivik, Nanushuk, and Itkillik lakes.

Depth (m)	Galbraith		Irgnyivik	Nanushuk	Itkillik[a]
	June	August			
0	7.5	16.0	13.5	11.0	17.4
1	7.5	16.0	no data	no data	17.4
2	7.5	16.0			17.4
3	7.5	15.5			17.3
4	8.0	15.0			17.3
5	8.0	14.0			16.6
6	8.0	13.5			14.7
7	8.0	13.5			14.2
8	8.0	13.0			14.0
9	8.0	13.0			13.8
10					13.6

[a] data are from LaPerriere and Jones *unpublished*

APPENDIX H
Data File Listing

Appendix H. -Data files used in producing this report are archived in FDSLT94.ZIP. The following files are contained in the archived file:

Data file	Description
GALBBB94.XLS	Burbot biological data, Galbraith Lake 1994
GALBFYKE.XLS	Galbraith Lake fyke net sets
GALBHOOP.XLS	Galbraith Lake hoop net sets
GALBLT93.XLS	Lake trout biological data, Galbraith Lake 1993
GALBLT94.XLS	Lake trout biological data, Galbraith Lake 1994
GALBSETS.XLS	Galbraith Lake gill net sets, CPUE estimate
INDXGIL.XLS	Index gill netting: FL by lake, FL by mesh size
IRGNLT94.XLS	Lake trout biological data, Irgnyivik Lake 1994
IRGNSETS.XLS	Irgnyivik Lake net sets, CPUE estimate
ITKLGILL.XLS	Itkillik Lake net sets, CPUE estimate
ITKLLT94.XLS	Lake trout biological data, Itkillik Lake 1994
LTGEAR.XLS	Galbraith Lake lake trout catch by gear type
NANUGILL.XLS	Nanushuk Lake net sets, CPUE estimate
NANULT94.XLS	Lake trout biological data, Nanushuk Lake 1994